Patients' experience of wearing multimodal sensor devices intended to detect epileptic seizures: a qualitative analysis.

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Abstract

Background: The health management of patients with epilepsy could be improved by wearing devices that reliably detect when epileptic seizures happen. For the devices to be widely adopted, they must be acceptable and easy to use for patients and their views are very important. Previous studies have collected feedback from patients on hypothetical devices, but very few have examined experience of wearing actual devices.

Purpose: This study assessed the first-hand experiences of people with epilepsy using wearable devices, continuously over a period of time. The aim was to understand how acceptable and easy they were to use, and whether it's reasonable to expect that people will use them.

Materials and Methods: Adults with a diagnosis of epilepsy admitted routinely to a hospital epilepsy monitoring unit were asked to wear one, or more, wearable biosensor devices, tested for seizure detection. The devices are designed to continuously monitor and record signals from the body (bio-signals). Participants completed semi-structured interviews about their experiences of wearing the device(s). A systematic thematic analysis extracted themes from the interviews, focusing on acceptability and usability. Feedback was organised into 1) participants' experiences of the devices, any support they required and reasons for stopping wearing them; 2) their thoughts about using this technology outside a hospital setting

Results: Twenty-one people with epilepsy wore one, or more, wearable devices for an average of 112.81 (SD=71.83) hours. Participants found the devices convenient, and had no problem wearing them in hospital or sharing the data collected from them with the researchers and medical professionals. However, the presence of wires, bulky size, discomfort and need for support, moderated experience. Participants' thoughts about wearing them in everyday life were strongly influenced by how visible and perceived accuracy. Willingness to use a smartphone app to complete questionnaires depended on the frequency, number of questions and support.

Conclusions: Overall, this work provides evidence about the feasibility and acceptability of using wearable devices to monitor seizure activity in people with epilepsy. Key barriers and facilitators to use while in hospital and hypothetical use in everyday life were identified and will be helpful for guiding future implementation.

Key words: epilepsy, acceptability, feasibility, qualitative analysis, wearables, seizure detection.

Introduction

Epilepsy is a common neurological condition that affects more than 50 million people globally [1]. It is associated with significant morbidity and mortality [2, 3]. Many important treatment decisions are based on the clinician reviewing the frequency and pattern of occurrence of seizures. These are usually self-reported by the person with epilepsy, for example in a seizure diary. However, there is good evidence that self-reported seizure occurrence may be inaccurate and unreliable [4-6].

It may be possible to reliably detect seizures by tracking physiological and behavioural variables in a person, for example, their heart rate, movements and electrical conductance of the skin. These might change before, during and after a seizure [7, 8]. Remote health technologies may be used, using biosensors that continuously monitor and record signals from the body. These can detect seizures and make a reliable log of epileptic activity. The data collected can be shared with medical professionals. The sensors can be built into clothing or devices that are worn continuously, known as 'wearables'.[9].

Although there is growing evidence of the ability of wearables to detect seizures [e.g., 10, 11] there is much less data on whether wearing such devices is acceptable to people with epilepsy. Preliminary surveys suggest that about 80-94% are interested in using them to track seizures. They are open to different forms of wearables, including wrist worn devices and patch electrodes (stuck on the skin) [8, 12]. However, previous research also suggests that wearables should be inconspicuous, unobtrusive, non-stigmatising, comfortable to wear and attractively designed [13, 14]. These criteria are not always

the top priority when the devices are being designed. In addition, people with epilepsy have voiced concerns about the confidentiality of data collected [8] although others have suggested that this is less of a problem [15]. Technical assistance and clinical support, for example from a doctor, have also been highlighted as extremely important in making the device more acceptable. [8, 14].

The purpose of this study was to evaluate acceptability of wearable devices in people with epilepsy, specifically in individuals who have used them, rather than discussing idealised, theoretical devices. This is a novel study that explores users' experience of wearables worn on the wrist, arm or head, while undergoing a routine video-EEG assessment in a hospital epilepsy monitoring unit. We were also interested in participants' views of using wearables and other technologies, for example smartphone apps, outside hospital, to track or potentially predict seizures in their daily life.

Methods

Design

This was an observational study involving semi-structured interviews following a topic guide, on acceptability of wearable sensor devices. The interviews were carried out after people with epilepsy had worn one, or more, wearable biosensors continuously, during a routine video-EEG assessment in a hospital epilepsy monitoring unit. The data were analysed using qualitative techniques.

The interview and study procedures were approved by the London-Fulham Research Ethics Committee (16/LO/2209; IRAS project ID 216316).

Participants

Participants were eligible if they were between 18 and 80 years, had a diagnosis of epilepsy and were able to give informed consent. People were excluded if they had an established diagnosis of

Psychogenic Non-Epileptic Seizures (PNES) as their only seizure type, or severe behavioural/cognitive difficulties.

Procedure

Clinical and demographic information, such as age and seizure frequency, were collected. The interviews lasted up to 25 minutes and were audio-recorded. They were conducted by a trained Clinical Psychologist using a semi-structured framework covering:

- Experiences of using the wearables
- Support required while using the wearables
- Concerns they may have, for example the comfort, appearance and data privacy/security
- Reasons for stopping to wear a device
- Thoughts about using technology, such as wearables and smartphone apps, outside hospital

The devices

Five wearable biosensors were used to monitor a range of bio-signals, alongside routine scalp EEG and video recordings. The E4 (Empatica Inc., Cambridge, MA, USA) and Everion (Biovotion AG, Zurich, Switzerland) devices were CE or FDA marked for human use and designed for continuous, real-time data acquisition in daily life. A bespoke sensor armband (IMEC, Leuven, Belgium), Epilog (Epitel Inc., Salt Lake City, UT, USA) and Sensor Dots (Byteflies NV, Antwerp, Belgium) were "research sensors". Further characteristics of these devices are detailed in Table 1. Each participant was asked to self-manage their devices where possible (e.g. turning them on and off and recharging if needed). The research team monitored how participants were doing every 24 hours and provided help when requested.

[Insert Table 1 here]

Data Analysis

Audio recordings were transcribed and then a thematic analysis was performed using NVivo Software Version 12. All transcripts were coded by two researchers working independently (A.B & S.S.) and the results discussed to reach the final conclusions.

Results

Participants

Forty-four patients with uncontrolled seizures were admitted for a long-term video-EEG in the Epilepsy Monitoring Unit at King's College London between January 2018 and February 2019. Twenty-one participants were selected from this sample to be interviewed based on which devices they were wearing (we aimed to interview 5 or 6 people per device). They also had to be willing to take part, even if they had decided to remove the devices during the study.

The characteristics of the 21 participants are summarized in Table 2. Five participants wore a single device, seven wore two devices (at the same time), and nine participants wore three devices (at the same time). As a result, each device was used a different number of times: Bespoke armband was worn sixteen times, E4 eight times, Everion six times, Sensor Dots five times, Epilog seven times. The average time wearing the devices across the entire sample was 112.81 (SD=71.83) hours**.** See supplementary file A for further details for each participant. Seven participants had previous experience of using a wearable bio-sensor device, for example a Fitbit, in their daily life.

[Insert Table 2 here]

Participant experiences

Information from the interviews was subdivided into experience of wearables in hospital and views on home-based use of technology. Under these topic headings, seven major themes and 22 minor themes emerged. Minor themes were broken down further into subthemes, where this helped understanding. These themes are summarised in Table 3 and are described in detail, with examples, below. A further deductive analysis was conducted, to extract the main 12 barriers to using the wearables and nine facilitators to engagement with each of the wearables (see Table 4 for more details).

[Insert Table 3 here]

[Insert Table 4 here]

Experience of wearing devices in hospital

Convenience and practicality of the devices

The wearables were **convenient** and preferable to the EEG sensors placed on their head.

> '*I just think it's a very good system and a lot easier to manage than like an EEG*' (Participant 6)

> '*EEG, it's not been much of a difference before I got my arm bands, it just seems like another attachable thing to the EEG, but I would like, the devices I like, they're just simple, you can take it off, put it back on, rather than the way this is on my head*' (Participant 12)

Many people said that they had **no problems** with the wearables. However, **some practical issues** were raised as key considerations when speaking about acceptability, such as:

- ***Visibility*** of the wearable, with people preferring discreet devices

- ***Support*** with fitting or switching on devices and charging. This mostly required help from the research team, which had very positive feedback.
- ***Stability*** of the device. The strength of the adhesive to secure the wearables that are attached with patches was important for keeping them securely in place. In some cases, wearables came loose during the study. This was mostly a concern for the flexible position devices, such as wearables attached to the head, and this sometimes happened while sleeping or during a seizure.

'*I found the ones on the head alright because they were out of my way, they were somewhat comfortable, the only issue with them is that after two days they started, well the glue started to wear off*' (Participant 18)

Other devices, such as the armbands, were typically found to stay securely in place throughout the test period.

The wearable that required additional ***wires/electrodes*** (the bespoke armband from IMEC), was more of a nuisance for some participants, especially when engaging in personal care activities. For example, it got caught on clothing. Some participants described a preference for other more ***removeable*** options, such as armbands without any wires (the Everion).

'*the Biovotion it makes it easier cause then you don't have the sort of the little sticky tabs as well on your chest and around there just to work, you've just got the single one on your arm*' (Participant 8)

In one case (participant 1), some limits to the ***placement*** of wearables arose for medical reasons. This included the need to position devices away from a venous line site on the arm and because of previous injuries.

Overall, **comfort** was of great importance. Someone commented that they had been ***undisturbed*** by the wearables, even during sleep.

> '*I thought I'd give it a go sleeping on it [Epilog], and it didn't really make a difference sleeping on it last night, so yeah, all week like I was expecting it to, I've not slept on it, because I was expecting it to be like uncomfortable or end up coming off when I were sleeping or whatever, but yeah it didn't end up coming off or whatever, it was just like a normal night's sleep*' (Participant 19)

However, some reported a ***skin irritation or discomfort*** with a Velcro arm band (both relating to the IMEC device).

Appearance of the device also influenced experience. For the people who compared their experience to wearable devices they already owned, some said that the wrist band (E4) was ***similar to a previous smartwatch***, others said it was ***larger***. ***Preferences varied*** for the wrist band versus the arm bands within the group. Participants made observations that some wearables could be ***discreetly hidden*** under clothes, or were inconspicuous, or even ***fashionable***, for example like a fitness tracker.

Table 4 lists the barriers and facilitators extracted from the interviews, for each device. While there were challenges associated with all devices, on balance, there was a general preference for **wrist and arm worn devices** over **flexible position devices**.

Views on sharing data

Participants were asked about their views on data being automatically collected through the wearable devices. Most participants reported **no problems** and saw positives to sharing this information. One person pointed out the sensitivity around some types of **personal data**, including ***identity*** and ***location.*** They highlighted the importance of **consent procedures** in terms of setting up these arrangements. Participants thought that sharing data, such as mood, activity and number of seizures with **healthcare professionals** could lead to beneficial actions such as:

- ***Adding information to medical records;***
- ***Pinpointing patterns***;
- ***Changing medication.***

Deciding to remove wearables

Three participants were interviewed after **deciding to remove the wearables**. Their reasons varied. One reported ***discomfort*** in relation to an arm band (IMEC device) after 1 day. Another removed the same device due to ***confusion*** after experiencing a seizure. Another participant saw ***no benefit*** in continuing after 3 days of data collection with both flexible position devices (Sensor Dots and Epilog).

Views on home-based technology use

Use of wearable devices

Many participants endorsed wearable devices as an **interesting and good idea** to try to detect seizures in real-time and be able to move around, in the hospital or at home.

> *'I think that having other devices, especially when you're at home it's also a better environment than being at the hospital cause it's not really your home environment (Participant 7)'*

When asked about **willingness to take part** some agreed, but others said they were ***unwilling***. For some, this was due to the ***effort*** required or pressure to commit to doing something. However, one person raised concerns about other people wanting the device and being the target of ***crime,*** for example, devices being stolen. Others were cautious about the questions that people might ask, including fear of ***discrimination***.

> *'I wouldn't wear a device on my arm where I live, they'd probably think I just got out of prison or something, it's a very rough area, and it's very, no I wouldn't wear it. I'd wear it inside, but no, yeah* '(Participant 1).

Factors that were raised as important to **user experience** in hospital, for example ***comfort, convenience*** and ***ease of use***, were also important to consider outside of hospital.

> '*I'd say if it's comfortable and if it's very easy to use then they'd be absolutely fine with it*' (Participant 18)

Outside of hospital, wrist and arm worn devices were thought to be more acceptable than head worn devices because they were less visible.

> '*the big black plastic buttons on my head are a little bit weird, but given that I'm covered in strange, my head is covered in strange white wires, so big black buttons didn't seem too dramatic. But yes, those would've looked a bit odd in isolation out on the streets. I mean saying that, the one on my neck is much less noticeable, and then I've got this thing on my arm which looks like the kind of thing people slot their iPhone into while they're running, so that's very unnoticeable*' (Participant 14)

Participants were divided about ***additional functions***, such as a watch face. Some said it would be useful and others not. Overall, comfort and accuracy seem more important than any other additional functions, such as GPS or medication alerts.

For some, there was an additional consideration of the ***length of time*** they would wear the device(s). Some thought that it could be worn only during specific time periods where it was more convenient or useful, such as ***at home*** and ***at night***. Others were willing to wear a device for as long as it took, as long as the device was comfortable. It was suggested that the device might become ***part of a person's routine***.

In relation to this, one person mentioned the importance of having family members to ***support*** him with the use of the device for a prolonged time at home:

> *'As long as I know how to do it, and I'm surrounded by family, so they'd be able to help me' (Participant 17)*

It may be important to note that some felt that there would be the need for ***enough personal benefit***, for example, the device being part of their medical care.

> '*if it was part of a longer study, just because of what I do and the other pressures I have on me, there would have to be a direct benefit to me as well*' (Participant 4)

> '*well I wouldn't mind for a period of time maybe, um, comfort is important to me, um, I don't mind so much but uh it does have a slight tendency to cause a little bit of itchiness and stuff like that so that might irritate me after a while, but I could wear it for a period of time if I knew it was helping and stuff like that'.* (Participant 10)

Use of a smartphone app

Participants were asked about using a **smartphone app** while they were wearing the device(s), to gather and display data. People could see the ***value*** in this, for example to:

- Reduce repetition of information
- Know that the device is gathering data
- Raise awareness of their health condition
- Provide motivation, through feedback from the app

They would be willing to complete ***simple questionnaires***, but acceptability of the ***frequency*** of questionnaires varied between individuals. One person suggested that ***family members/carers*** might like to input into the system.

> *'If it takes a minute to fill in three times a day then that's not much of a problem. But if it's taking ten minutes each time then that would be too long'* (Participant 14)

> *'short questionnaire, cause otherwise people will think like, I'm getting up in the morning, daily routine and putting them on, and some people might also think okay now I've gotta go and do the app, so, I would probably say one a day, a short one, yeah'* (Participant 15)

However, there were also concerns raised about barriers relating to ***digital exclusion,*** due to people not owning a smartphone, not being confident with using apps, or simply disliking them.

> '*I'm not particularly keeping up with things like apps you know, I've got apps on here, I know what they do, but already I've gone onto this [app] and its consumed so much of the storage on my phone I'm now going to have to change my phone*' (participant 20)

A solution offered was to complete questionnaires using a computer.

Discussion

This is a novel study, where we collected user feedback from people with epilepsy after continuously wearing devices in an epilepsy monitoring unit. To the best of our knowledge, there are no previous studies reporting patients views on wearing multiple devices simultaneously for an extended time period. Each device had strengths and weaknesses that are very important for long-term use, and some devices were more tolerable than others. The provision of a removable but securely fitted device with a long battery life that looks familiar (like a watch or a fitness tracker), were preferable. Our participants were interested in the idea of using a wearable outside the hospital for an extended period. They acknowledged that wearing a device continuously in a natural setting could be the ideal solution for collecting more accurate data about seizures. Despite this, some participants suggested some barriers to wearing a device constantly. If the wearable were to be combined with a smartphone app, functions would have to be simple and quick to use.

These findings build on previous research that focused on hypothetical scenarios and they echo, as well as extend, their conclusions. It has been repeatedly reported that motivation to use wearables will depend on the accuracy and reliability of the device to detect or predict seizures, with a low false positive/false negatives rates [8, 13, 14, 16]. In line with previous findings, participants in this study expressed preferences for devices that function without being too noticeable [12]. Additional wearable devices were all relatively discreet in hospital. However, when asked about wearing these devices in their daily life, people were not keen on wearing flexible position devices. Specifically, these were devices worn on the head, or with wires that could not be covered, or that looked out of place. Previous research has already highlighted problems with stigma associated with epilepsy, [14, 17] so the visibility of wearable devices will be key for the future use of this technology. Other barriers and facilitators to user experience are also in line with previous findings. For example, the need to consider devices with a long battery life and giving the user the ability to remove or charge the device by

themselves [13, 15, 16]. Some barriers were overcome with researcher support, but in a less controlled environment this may be more of a problem. Previous studies have suggested that users of wearables and smartphone are provided with technical support, in the form of written documents, video tutorials or telephone-based.[8, 13].

The interest in exploring the efficacy and accuracy of wearables for the detection and prediction of epileptic seizures is clear. There is a number of new studies emerging and devices available on the market [10, 18, 19]. Despite this, the use of wearables to improve health-management and safety in the routine of people with epilepsy is not yet realised. Only a small percentage of our participants were using, or had worn, a device to monitor their epilepsy (2/21 9%). An adequate level of acceptability and usability could be the key to obtain a suitable device for continuously detecting seizures in daily life.

Limitations

Participants were recruited from a sample of individuals experiencing frequent seizures. The extent to which these findings generalize to the wider community of people with epilepsy is unknown. Participants wore different combinations of devices for slightly different periods of time. They were not provided with a choice of these devices at the start of the study, so it was not possible to investigate participant free choice. Participants were not given real-time feedback from the research team about the ability of each device to detect seizures when they occurred, as data were analysed after the end of the recording. This will have certainly influenced their perception about accuracy and effectiveness and consequently their judgment when balancing between device form and perceived precision.

Conclusions

Obtaining feedback from patients after direct and continuous experience of wearing one or multiple devices, is the only way to fully understand the practical and technical issues that people with epilepsy face, when interacting with new technologies. From previous research we know that the effectiveness of the device in detecting seizures is important. From this study we now know that the visibility, the comfort, the possibility to remove the device and the availability of support are also all essential. Where discomfort was experienced, there was a risk of people deciding to discontinue wearing a device. Similarly, if there was any confusion about the purpose or benefit to the user, this was also a major barrier to continuing. The possibility to stream and share physiological data, directly from the device to a clinician/researcher, was generally well accepted. Stigma and fear of social exclusion are significant issues that still demotivate people with epilepsy when approaching and using new technologies. The hypothetical scenario of wearing a device at home was of interest to participants, suggesting that collecting data in a routine setting could be possible but the actual uptake is still unknown and needs further investigation with a focus on how to overcome any perceived costs.

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Conflict of Interest:

The authors declare no conflict of interest.

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Table 1. Technical characteristics of wearable devices

Device Name	**Sensor modalities**	**Position on body**	**Data logging / streaming**	**Battery life (manufacturer's claim)**
E4 (Empatica)	• Photoplethysmogram (PPG Sensor) [Blood Volume Pulse], • 3 Axis Accelerometer [Motion Base Activity], • Electrodermal Activity (EDA Sensor) [fluctuating changes in skin electrical properties], • Infrared Thermopile (skin temperature), • https://www.empatica.com/research/e4/	Wrist	Continuous streaming (*Bluetooth Streaming Mode**) or Internal memory up to 60 hours data (*Recording Mode*)	24+ Hours (*Bluetooth Streaming Mode*) 48+ Hours (*Recording Mode*)
Bespoke sensor armband (IMEC)	• 3-Lead electrocardiography [Heart Rate], • 3 Axis Accelerometer [Motion Base Activity], • Double channels electromyography (EMG) [muscle electrical activity], • Electrodermal Activity (EDA Sensor) [fluctuating changes in skin electrical properties], • https://www.imec-int.com/en/articles/sensor-bracelet-detects-epileptic-seizures	Upper arm (with electrodes attached on the chest, shoulder and arm)	Internal memory data storage up to 7 days (*Recording Mode*)	96 Hours (*Recording Mode*)
Everion (Biovotion)	• Photoplethysmogram (PPG Sensor) [Blood Volume Pulse], • 3 Axis Accelerometer [Motion Base Activity], • Electrodermal Activity (EDA Sensor) [fluctuating changes in skin electrical properties], • Infrared Thermopile (skin temperature), • https://www.biovotion.com/everion/	Upper arm (without electrodes)	Continuous streaming (*Bluetooth Streaming Mode**)	32 Hours (*Bluetooth Streaming Mode**)
Epilog (Epitel)	• Single channel electroencephalography (EEG). • https://www.epitel.com/	Flexible Position Device. Can be placed in two different positions on the scalp (left/right frontal or left/right behind the ear).	Local data storage on device up 10 days (*Recording Mode**) or Continuous streaming (*Bluetooth Streaming Mode*)	240 Hours
Sensor dots (Byteflies)	• Photoplethysmogram (PPG Sensor) [Blood Volume Pulse], • Electrocardiogram (ECG) [Heart Rate],	Multiple simultaneous sites (up to 5	Up to 24 Hours Internal	24 Hours

	• 3 Axis Accelerometer and Gyroscope [Inertial Measurement Unit (IMU)], • Electrodermal Activity (EDA Sensor) [fluctuating changes in skin electrical properties], • Double channels electromyography (EMG) [muscle electrical activity], • Single channel electroencephalography (EEG). • https://www.byteflies.com/	sites), can be positioned flexibly according to clinician or user.	Memory (*Recording Mode**)

*** For the study we used this modality.**

Table 2. Demographic & Clinical Characteristics

Demographic & Clinical	
Gender Female: N (%)	7 (33.3)
Age (years): mean ± SD	40.4 ± 13.3
Epilepsy Duration (years): mean ± SD	21.8 ± 13.5
Self-reported seizure frequency (seizure/month): mean ± SD	22.3 ± 38.0
Number of AEDs: mean ± SD	2.7 ± 1.1
Period of data collection prior to interview (days) mean ± SD	3.09 ± 1.59
Participants reporting previous experience with a wearable device N (%)	7 (33.3)
Duration of prior experience with wearable device (months): mean ± SD	7.3 (4.5)
Educational level completed: N (%)	
University graduate	6 (28.5)
A level/ B-tech/ Apprenticeship (high school exams taken age 18)	9 (42.8)
GCSE (high school exams taken age 16)	3 (14.3)
Did not achieve GCSE	3 (14.3)
Ethnicity: N (%)	
White	16 (76.2)
Black/African/Caribbean/Black British	3 (14.3)
Mixed/Multiple Ethnic Group	1 (4.8)
Other	1 (4.8)
Employment: N (%)	
Full-time	10 (47.6)
Part-time	1 (4.8)
Unemployed	5 (23.8)
Retired	3 (14.3)
Student	2 (9.5)

AEDs: antiepileptic drugs, SD: standard deviation

Table 3. Major themes, minor themes and subthemes emerging from the discussions.

Topic areas (2)	Major themes (7)	Minor themes (22)	Subthemes (32)
Experience of wearables in hospital	Convenient/no problems		
	Problems with flexible position devices (loosening)		
	Other practical issues	Visibility of device(s)	
		Support needed	
		Stable position of device(s)	
		Presence of wires/electrodes	
		Placement of device(s)	
		Removeable	
		Comfort	Undisturbed by device(s)
			Skin irritation or discomfort
		Appearance	Preferences varied
			Discreet or inconspicuous
			Fashionable fitness tracker
			Like a smartwatch
			Size of device(s)
	Views on sharing data	No problems	
		Some concerns about personal data	Identity
			Location
		Importance of consent procedures	
		Involving healthcare professionals	General Practitioner (GP)
			Specialist, e.g. Neurologist
		Leads to action	Adding information to medical records
			Pinpointing patterns
			Changing medication

	Deciding to remove wearables	Discomfort	
		Confusion	
		No benefit	
Views on home-based use of technology	Use of wearables	Interesting or good idea	
		Willing to take part	Length of time
			Night use
			Home use
			Dependent on personal benefit
			Becoming part of routine
		Unwilling to take part	Effort
			Crime
			Discrimination
		User experience	Comfort
			Ease of use
			convenience
			Less visible
			Support
			Additional feature, e.g. watch
	Use of a smartphone app	Value	Involvement of family/carers
			Simple questionnaires
			Frequency of questions
		Concerns	Digital exclusion

Table 4. Barriers and facilitators to positive user experience across all wearables, split by arm, wrist and flexible position devices.

	Arm band		Wrist band	Flexible position device	
Barriers	**Everion (BIOVOTION)**	**Bespoke sensor armband (IMEC)**	**E4 (Empatica)**	**Epilog (Epitel)**	**Sensor Dots (BYTEFLIES)**
Presence of stickers (stuck to clothing, caused skin irritation, detached)		X		X	
Presence of wires (not long enough, nuisance when going to the toilet, got in the way)		X			
Needed to keep switching it on and unsure if device was working			X		
Battery ran out or needed to remember to charge or change device	X		X		
Came loose (Velcro strap)		X			
Discomfort (needed to reposition device, caused skin irritation, problems during sleep)		X		X	
Too noticeable (not able to cover with clothes)		X	X	X	
Visible flashing light			X		X
Cumbersome/large		X	X		
Needs removing to take blood pressure	X	X			
Wore a watch already			X		
Limited choice of placement		X			
Facilitators	**Everion (BIOVOTION)**	**Bespoke sensor armband (IMEC)**	**E4 (Empatica)**	**Epilog (Epitel)**	**Sensor Dots (BYTEFLIES)**
Removeable	X	X	X		
Familiar (like a watch or a fitness tracker)	X		X		
Secure band	X				
Practical and simple		X		X	
Able to forget that they were wearing the device	X	X	X	X	X
Right size		X			
Plastic so won't break			X		
Discreet (can wear underneath clothing)	X	X			X
Comfortable during sleep	X	X	X		

Supplementary file A: List of participants and devices worn.

	Arm band (n=16)		Wrist band (n=8)	Flexible position device (n=9)		Data collection duration (days) prior	Data collection duration (hours)
Participant	**Everion (BIOVOTION)**	**Bespoke sensor armband (IMEC)**	**E4 (Empatica)**	**Epilog (Epitel)**	**Sensor Dots (BYTEFLIES)**	**Interviews**	**in total**
1		X				1*	24
2			X			4	264
3			X			6	216
4		X				2	44
5	X	X	X			2	70
6	X	X				3	72
7		X	X			3	70
8	X	X				2	142
9	X	X	X			2	138
10	X	X				2	72
11		X				2*	49
12	X	X	X			2	114
13		X			X	5	119
14		X		X		4	93
15				X	X	2	72
16		X		X		2	111
17		X		X	X	2	232
18				X	X	3*	20
19		X		X		5	48
20			X	X	X	7	213
21		X	X	X		4	186
Total	**6**	**16**	**8**	**8**	**5**	**Mean 3.09 (1.59)**	**Mean 112.81 (71.83)**

* Indicates participants who chose to remove the device before the end of participation in the study